TRANSLATION

I, Yuko Mitsui, residing at 4-6-10, Higashikoigakubo, Kokubunji-shi, Tokyo, Japan, state:

that I know well both the Japanese and English languages,

that I translated, from Japanese into English, Japanese Patent Application No. 2000-071128, filed on March 14, 2000, and

that the attached English translation is a true and accurate translation to the best of my knowledge and belief.

Dated: March 2, 2004

Yuko Mitsui

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PATENT OFFICE
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[Title of the Invention] SCANNING MECHANISM AND MECHANICAL SCANNING MICROSCOPE USING THE SAME

[What is claimed is:]

[Claim 1] A scanning mechanism comprising:

a drive portion for moving an object to be moved for a scanning operation; and

a holding portion for holding the drive portion at a position in the vicinity of the center thereof.

[Claim 2] A scanning mechanism comprising:

a first drive portion for moving an object to be moved in a first direction for a scanning operation;

a holding portion for holding the first drive portion at a position in the vicinity of the center thereof; and

at least a second drive portion for moving the object to be moved in at least a second direction different from the first direction,

the scanning operation in the first direction performed by the first drive portion having a higher scanning frequency than scanning operations in other directions.

[Claim 3] A mechanical scanning microscope including the scanning mechanism according to claim 1 or 2.

[Detailed Description of the Invention]

[0001]

[Technical Field of the Invention]

The present invention relates to a scanning mechanism and an apparatus incorporating the same. The scanning mechanism of the present invention is used in, for example, a scanning

mechanism incorporated in a scanning microscope and an apparatus for observing or processing a sample or for recording information, to which a technique of the scanning microscope is applied.

[0002]

[Prior Art]

A stage mechanism for causing translational movement in XYZ directions or rotational movement of an object to be moved is one of the basic elements of a machine mechanism. Further, an automatic stage capable of controlling stage movement by using a drive mechanism such as a motor in accordance with a control signal such as an electric signal is used in every scene. A stage (movable stage) in the stage mechanism like this is held by a support portion of the stage mechanism which sets the stage in place. Thus, the stage can be referred to as a mechanism for changing a positional relationship of the object to be moved with respect to the support portion.

[0003]

A machine mechanism for repeatedly causing reciprocating movement or rotational or half-rotational movement of an object in a relatively short period of time is also referred to as a scanning mechanism. (Hereinafter, such a mechanical scanning mechanism will be simply referred to as a scanning mechanism unless otherwise specified.)

Such a scanning mechanism is mounted in, for example, a scanning microscope. As a scanning microscope apparatus in which such a scanning mechanism is mounted, there are a scanning probe microscope, a laser scanning microscope, or

an electronic scanning microscope which is of a type capable of obtaining an image by scanning a sample with an electronic beam being fixed.

[0004]

A scanning probe microscope (SPM) is a scanning microscope which mechanically scans a mechanical probe to obtain information of a sample surface, and includes a scanning tunneling microscope (STM), an atomic force microscope (AFM), a scanning magnetic force microscope (MFM), a scanning capacitance microscope (SCaM), a scanning near-field optical microscope (SNOM), a scanning thermal microscope (SThM) and others. In recent years, a nano-indentator and the like, which makes an indentation by pressing a probe made of diamond against a sample surface and checks hardness and the like of the sample by analyzing how the indentation is made, is regarded as one of the SPMs widely used, together with the above-described various microscopes.

[0005]

The scanning probe microscope can obtain surface information in a desired sample area through a mechanical probe while performing relative raster scanning or XY scanning with respect to the mechanical probe and the sample, thereby mapping the obtained information on a TV monitor. Further, an SNOM and the like can perform fine processing or optical information recording by causing a light beam emitted from an end of a mechanical probe to act on a workpiece. Furthermore, a nano-indentator can form irregularities on a sample surface to similarly perform fine processing or information recording.

[0006]

In such a scanning probe microscope, a relative position along the Z axis of the sample and the probe, i.e., a distance between the sample and the probe is subjected to feedback control in such a manner that the interaction of the sample and the probe becomes constant during XY scanning. The movement along the Z axis is different from regular movement along the X axis and the Y axis but irregular in order to reflect the surface shape or surface state of the sample. The movement along the Z axis is generally referred to as Z scanning. The Z scanning has a highest frequency among those of XYZ scanning. A frequency of X scanning by the scanning probe microscope ranges from approximately 0.05 to 200 Hz, and a frequency of Y scanning corresponds to (the frequency of X scanning) / (Y scanning lines). A number of Y scanning lines is 10 to 1000. Furthermore, a frequency of Z scanning is approximately several-fold to 100-fold of pixels per one line of X scanning with respect to a frequency of X scanning.

[0007]

For example, in order to fetch an image having 100 pixels along the X axis and 100 pixels along the Y axis in one second, a frequency of X scanning is 100 Hz; a frequency of Y scanning, 1 Hz; and a frequency of Z scanning is not less than 10 kHz. It is to be noted that a scanning frequency of this example is presently the highest scanning frequency for the scanning probe microscope, and the frequency of X scanning is usually approximately several Hz. The scanning mechanism must be stable against external vibrations, and vibrations generated

from the scanning mechanism itself by the internal scanning operation must be suppressed in order to realize such a high scanning frequency as in this example.

[0008]

[Objects of the Invention]

A movement of a stage of the scanning mechanism acts on the support portion supporting the stage as a counteraction, in other words, the stage movement transmits a vibration to the support portion. The transmitted vibration acts on the support portion to vibrate it, which in turn acts on the stage again to vibrate it. Therefore, the stage requiring accurate positional control must suppress the generation of such vibrations as much as possible. Moving the object slowly in order to decrease an acceleration of the stage is one effective method for suppressing the occurrence of vibrations. However, in a case where the object need to be moved to a desired position in a short period of time, the scanning mechanism cannot exhibit a required travel speed capability with the above method. In such a case, another contrivance for suppressing the vibration is required. Note that in the scanning probe microscope, for example, the case where the object needs to be moved to a desired position in a short period of time includes a case where images are high-speed scanned and captured in a short period of time and one where an object must be moved in a short period of time in Z direction due to a large surface irregularity of the sample.

[0009]

An object of the present invention is to provide

a scanning mechanism capable of suppressing generation of vibrations and thereby effecting accurate positional control.

[0010]

[Means for Achieving the Objects]

A scanning mechanism according to the present invention comprises a drive portion for moving an object to be moved for a scanning operation and a holding portion for holding the drive portion at a position in the vicinity of the center thereof.

[0011]

Another scanning mechanism according to the present invention comprises a first drive portion for moving an object to be moved in a first direction for a scanning operation, a holding portion for holding the first drive portion at a position in the vicinity of the center thereof, and at least a second drive portion for moving the object to be moved in at least a second direction different from the first direction, and the scanning operation in the first direction performed by the first drive portion has a higher scanning frequency than scanning operations in other directions.

[0012]

In another aspect, the present invention is a mechanical scanning microscope including the above scanning mechanism.

[0013]

[Embodiments of the Invention]

(First Embodiment)

FIG. 1 shows a mechanical scanning microscope, i.e., a scanning probe microscope having a scanning mechanism of

a first embodiment according to the present invention.

[0014]

In FIG. 1, a scanning probe microscope 100 basically has a part corresponding to a scanning probe microscope function and a part corresponding to an optical microscope function.

[0015]

The part corresponding to the scanning probe microscope function includes: a case 101; an optical sensor unit 102; a sensor unit Z stage 103; a slide glass 104; a slide glass holding portion 105; a cantilever chip 106; a scanning mechanism holding base 107; a scanning mechanism 200; an actuator drive circuit 112; a scanning control circuit 113; a feedback circuit 114; an AC/DC conversion circuit 115; an oscillation circuit 116; a pre-amp circuit 117; a semiconductor laser drive circuit 118; a computer 119; and a TV monitor 120.

[0016]

Further, the part corresponding to the optical microscope function includes: an optical illuminating system for microscope observation 110 including a light source lamp 139 and a lens 138; an optical observation system for microscope observation 111 including an eyepiece 140; a half prism 137; a microscope illuminating lamp power supply 121; and an objective 122 of the optical sensor unit 102 shared with the part corresponding to the scanning probe microscope function.

[0017]

Further description will be given as to the part of the scanning probe microscope function. The scanning mechanism

holding base 107 is supported at three points on the case 101 by three micrometer heads 135 (only two micrometer heads are shown in FIG. 1) which can be manually fed by a small amount. Furthermore, the scanning mechanism 200 is supported on the scanning mechanism holding base 107, and a sample 109 is attached to the scanning mechanism 200 in such a manner that the sample 109 faces downwards, namely, it is opposed to the cantilever chip 106 side. The scanning mechanism 200 applies micromotion scanning to the sample 109 along the X axis, the Y axis and the Z axis. The details of the scanning mechanism 200 will be fully explained later. The scanning mechanism 200 may include an adjustment mechanism for effecting rough adjustment of positions of a probe 132 of the cantilever chip 106 and the sample 109 in regard to each of the X axis, the Y axis and the Z axis.

[0018]

The optical sensor unit 102 measures movement of a cantilever 131 of the cantilever chip 106. This is an optical sensor which is of an optical lever type. The optical sensor unit 102 has: an objective 122; an objective supporting base 123; a prism 124; a polarized beam splitter 125; a collimator lens 126; a semiconductor laser 127; a laser position adjustment stage 128; a two-split photodiode 129; a photodiode position adjustment stage 130.

[0019]

A light ray emitted from the semiconductor laser 127 is turned into a parallel beam by the collimator lens 126 and then reflected by the polarized beam splitter 125. Thereafter, this

light beam is further reflected by the prism 124 and enters the objective 122. The parallel beam is condensed on a rear surface of the cantilever 131 of the cantilever chip 106 by the objective 122. The light beam reflected by the rear surface of the cantilever 131 proceeds in the opposite direction. It passes through the polarized beam splitter 125 and further goes straight to reach the two-split photodiode 129. The angle displacement of the cantilever 131 is reflected on movement of a light spot on the two-split photodiode 129 and outputted as an electric signal.

[0020]

The objective 122 of the optical sensor unit 102 constitutes the optical illuminating system for microscope observation 110 and the optical observation system for microscope observation 111 as well as the optical system for optical microscope observation, and enables an optical microscope observation of the sample 109. The objective 122 is an objective for use in an optical microscope and has, for example, a twenty-fold magnification.

[0021]

The sensor unit Z stage 103 is provided for performing rough adjustment of a position of the optical sensor unit 102 including the objective 122. The sensor unit Z stage 103 moves the objective 122 included in the optical sensor unit 102 up and down to effect focusing of the optical sensor or focusing for microscope observation.

[0022]

The slide glass holding portion 105 holds the slide glass

104. A piezoelectric excitation device 133 for exciting the cantilever 131 is fixed to the slide glass holding portion 105 at a position apart from an attachment portion for the cantilever chip 106. An alternating voltage in the proximity of a resonance frequency of the cantilever 131 is applied to the piezoelectric excitation device 133. The piezoelectric excitation device 133 vibrates in accordance with the application of this voltage, and this vibration is transmitted to the cantilever chip 106 to vibrate the cantilever 131.

[0023]

In measurement for vibrating the cantilever 131 in this manner, a displacement signal of the cantilever outputted from the optical sensor unit 102 becomes alternated. The AC/DC conversion circuit 115 converts this signal into a direct-current signal. In measurement in which the cantilever 131 is not vibrated, this circuit may be bypassed so that it does not operate.

[0024]

Moreover, FIG. 1 shows the state of observation in a liquid. Water 134 drips from the vicinity of the sample 109 of the scanning mechanism 200 to the proximity of the slide glass 104 to which the cantilever chip 106 is fixed. Both the sample 109 and the cantilever chip 106 are positioned in water. In the case of performing measurement in air, the water 134 is not necessary.

[0025]

As shown in FIG. 1, the scanning probe microscope 100 includes an electric circuit and the like for

controlling/driving the apparatus. The operation of these circuits is similar to the circuit operation in the scanning probe microscope which has been conventionally proposed.

[0026]

A control signal of XYZ scanning is supplied from the computer 119 to the scanning control circuit 113. Reference character "Z" in FIG. 1 denotes a signal for adjusting a distance between a Z scanning actuator of the scanning mechanism 200 and the probe 132 of the cantilever chip 106. The signal "Z" is mainly outputted from the computer when setting measurement conditions, for example, at the time of force curve measurement before carrying out measurement. In addition, the computer 119 controls the oscillation circuit 116 to operate the piezoelectric excitation device 133 and vibrates the cantilever 131 in the vicinity of the resonance frequency thereof.

[0027]

When measurement starts, the actuator of the scanning mechanism 200 is scanned along the X axis and the Y axis based on a raster scanning control signal (designated by "X" and "Y" in the drawing) outputted from the computer 119. The displacement of the cantilever 131 based on the interaction of the probe 132 provided at the end of the cantilever 131 and the surface of the sample 109 is detected by the optical sensor unit 102, and the optical sensor unit 102 outputs the displacement signal. The displacement signal outputted from the optical sensor unit 102 is amplified by the pre-amp circuit 117 and inputted to the AC/DC conversion circuit 115. The

AC/DC conversion circuit 115 extracts a signal having a frequency component of a reference signal from the oscillation circuit 116 and converts the alternating signal into a direct-current signal.

[0028]

The feedback circuit 114 compares a setting signal directed by the computer 119 with an input signal from the AC/DC conversion circuit 115 and transmits a Z feedback signal Zfb to the scanning control circuit 113. The Z feedback signal Zfb serves as a scanning control signal of the Z direction actuator. The scanning control circuit 113 controls the actuator drive circuit 112 based on the Z feedback signal Zfb and drives the Z scanning actuator of the scanning mechanism 200. The computer 119 processes surface information of the sample as three-dimensional information based on scanning control signals "X" and "Y" generated by the computer 119 itself and a signal from the feedback circuit 114 and displays the result on the TV monitor 120.

[0029]

The scanning mechanism 200 of this embodiment will be further described in detail with reference to FIG. 2. As shown in FIG. 2, the scanning mechanism 200 comprises: a scanning mechanism holding base 201; actuator pedestals 202 and 203 fixed to the scanning mechanism holding base 201; and actuators 204, 205 and 206 attached to the actuator pedestals 202 and 203.

[0030]

The actuator 204 is extendable along, for example, the X axis and is substantially held by the actuator pedestal 202

through an actuator holding portion 207. Similarly, the actuator 205 is extendable along, for example, the Y axis and substantially held by the actuator pedestal 203 through an actuator holding portion 208. The actuator 206 is extendable along the Z axis and substantially held by the actuator pedestals 202 and 203 through actuator holding portions 209 and 210.

[0031]

Each of the actuators 204, 205 and 206 comprises, for example, a stacked piezoelectric device, and the piezoelectric device has, for example, a length of 10 mm and a cross section of 5 mm × 3 mm. It extends and contracts by 3 μm upon application of a voltage of 100 V. The actuators 204, 205 and 206 extend and contract along the X axis, the Y axis and the Z axis in accordance with application of a drive voltage through two lines extending therefrom, respectively.

[0032]

The actuator holding portion 207 holds the actuator 204 at a position in the vicinity of the center in dimension or the center of gravity thereof. The actuator holding portion 208 holds the actuator 205 at a position in the vicinity of the center in dimension or the center of gravity thereof. The actuator holding portions 209 and 210 hold the actuator 206 at a position in the vicinity of the center in dimension or of the center of gravity thereof.

[0033]

To the actuator 206 is attached a sample holding portion 211 for holding an object to be moved, for example, a sample.

The sample holding portion 211 has a sample base glass attached on an end surface thereof.

[0034]

The actuator 204 extendable along the X axis has a minute ball 212 attached on an end surface thereof facing the actuator 206 extendable along the Z axis, and the minute ball 212 abuts and is attached on one end portion side surface of the actuator 206 crossing the X axis. Similarly, the actuator 205 extendable along the Y axis has a minute ball 213 attached on an end surface thereof facing the actuator 206, and the minute ball 213 abuts and is attached on one end portion side surface of the actuator 206 crossing the Y axis.

[0035]

As described above, according to the scanning mechanism having the end surfaces of the actuators being in contact with the object through the minute balls, the minute ball provided to the actuator which does not extend and contract serves as a guide with respect to the object and does not obstruct movement of the object by another actuator which extends and contracts. Therefore, this scanning mechanism has an advantage that the linearity of the operation characteristic is high. The scanning mechanism of this type has been disclosed in, for example, Jpn. Pat. Appln. KOKAI Publication No. 9-89910, and its content is incorporated in the present specification for reference.

[0036]

The operation of the scanning mechanism 200 shown in FIG. 2 along the Z axis will now be described with reference to

FIG. 3 (a) typically illustrating the scanning mechanism 200. FIG. 3 (a) shows only members necessary for the following explanation.

[0037]

In FIG. 3 (a), the actuator 206 comprises a stacked piezoelectric device, and its part close to the center in dimension is fixed to the actuator pedestal 203 provided to the scanning mechanism holding base 201 by an actuator holding portion 210 made of silicone rubber having an adhesive effect. The both side portions of the stacked piezoelectric device 206 extend and contract in opposed directions as shown by the arrows in accordance with application of a voltage with a position in the vicinity of the center in dimension fixed to the actuator holding portion 210 as a reference.

[0038]

In general, the operation of the actuator gives the vibrations or impact due to the counteraction of the actuator operation to the actuator holding portion holding this actuator. Such vibrations or impact results in oscillation of the scanning mechanism. In the case of scanning at high speed or scanning using a high frequency, it is desirable to suppress the vibrations of the scanning mechanism as much as possible.

[0039]

In this embodiment, since a position of the actuator 206 in the vicinity of the center in dimension thereof is held, the impact is balanced on the boundary face between the actuator 206 and the actuator holding portion 210 indicated by a symbol X in the drawing, and the vibration transmitted to the actuator

pedestal 203 or the scanning mechanism holding base 201 can be suppressed. This can be better understood by comparing with the later-described comparative examples shown in FIGS. 7, 8, and 9.

[0040]

Although the above has described suppression of generation of the vibrations concerning the Z scanning actuator 206, the occurrence of the vibrations can be similarly suppressed with respect to the X scanning actuator 204 and the Y scanning actuator 205.

[0041]

In the prior art scanning mechanism, the actuator such as a stacked piezoelectric device described above usually has one end portion being held in order to assure a large scanning range, i.e., a long stroke. Thus, the counteraction of the operation of the actuator affects the holding portion, and this oscillates the scanning mechanism.

[0042]

On the contrary, in the scanning mechanism in which the actuator is held at a position close to the center in dimension as in this embodiment, since the part of the kinetic system close to the center of gravity is held, oscillation at the holding position can be suppressed. As a result, this scanning mechanism has less vibrations and stably operates with respect to scanning at high speed.

[0043]

With the scanning probe microscope illustrated in FIG. 1, a sample (a latex ball having a diameter of 150 nm) in a liquid

was able to be measured at an image fetching speed that an observation range on the sample surface 0.5 μm × 0.5 μm is fetched at 0.5 second/screen, in data fetch of 100 pixels/line concerning the X axis and 100 lines (10,000 pixels/screen) concerning the Y axis. A value of the image fetching speed 0.5 second/screen is a quite short period of time in the scanning probe microscope. It is to be noted that a cantilever made of silicon nitride having a resonance frequency in a liquid of 395 kHz, a length of 9 μm, a width of 2 μm and a thickness of 0.09 μm was used.

[0044]

Additionally, since a commercially available actuator can be used as the actuator 206 without any modifications, the scanning mechanism of this embodiment is advantageous in that the total cost can be reduced.

[0045]

(Second Embodiment)

A second embodiment according to the present invention will now be described with reference to FIG. 3 (b). FIG. 3 (b) is a view corresponding to FIG. 3 (a) and shows only members necessary for the following explanation. Further, in these drawings, like reference numerals denote like or corresponding parts.

[0046]

In the scanning mechanism of this embodiment, the Z scanning actuator 305 has an actuator connection portion 308 consisting of, e.g., an aluminium block, and two stacked piezoelectric devices 306 and 307 connected to this actuator

connection portion 308. In general, the two stacked piezoelectric devices 306 and 307 are widely commercially available, and they are fixed to the actuator connection portion 308 by an adhesive so that they can linearly extend with the actuator connection portion 308 therebetween. Furthermore, a sample holding portion 211 is attached to a free end of the stacked piezoelectric device 306.

[0047]

As can be understood from the similarity with FIG. 3 (a), since the scanning mechanism of this embodiment also has the actuator 305 being held at a position in the vicinity of the center in dimension thereof, the scanning mechanism can stably operate with respect to high speed scanning with less vibrations.

[0048]

Moreover, in the scanning mechanism of this embodiment, the actuator connection portion 308 sandwiched between the two stacked piezoelectric devices 306 and 307 is held by the actuator holding portion 210 composed of, for example, silicone rubber. Therefore, the scanning mechanism of this embodiment has an advantage that an individual difference (difference in performance) of the scanning mechanism hardly noticeable with respect to a quantity of silicone rubber used for attaching the actuator 305, as compared with the scanning mechanism of the first embodiment.

[0049]

(Third Embodiment)

A third embodiment according to the present invention

will now be described with reference to FIG. 4. As shown in FIG. 4, the scanning mechanism of this embodiment comprises: a scanning mechanism holding base 401; an L-shaped actuator pedestal 402 fixed to the scanning mechanism holding base 401; two actuators 403 and 404 attached to the actuator pedestal 402; and an actuator 405 supported by the two actuators 403 and 404.

[0050]

Each of the actuators 403, 404 and 405 is, for example, a stacked piezoelectric device and extendable along the X axis, the Y axis and the Z axis, respectively. Each of the X scanning actuator 403 and the Y scanning actuator 404 has one end portion being fixed to the actuator pedestal 402. The highest scanning speed is demanded from the Z scanning actuator 405, and its part close to the center in dimension is fixed to the other end portion of each of the X scanning actuator 403 and the Y scanning actuator 404 by an adhesive.

[0051]

The Z scanning actuator from which the highest scanning speed is demanded, i.e., the stacked piezoelectric device 405 has both side portions symmetrically extending and contracting in the opposed directions, as indicated by the arrows, with its part close to the center fixed to the X scanning actuator 403 and the Y scanning actuator 404 as a reference. The impact generated due to the extending and contracting operation of the stacked piezoelectric device 405 can be, therefore, suppressed. Accordingly, the scanning mechanism of this embodiment can stably operate with respect to high speed scanning with less

vibrations.

[0052]

In addition, the scanning mechanism of this embodiment has the following advantages as compared with the scanning mechanism of the first embodiment. In the scanning mechanism of the first embodiment, the X scanning and Y scanning actuators are pressed against the Z scanning actuator through the minute balls. Therefore, pressurization becomes insufficient during extended use, and scanning along the X axis and the Y axis becomes unstable. On the contrary, in the scanning mechanism of this embodiment, since the Z scanning actuator 405 is fixed to the X scanning and Y scanning actuators 403 and 404 by the adhesive, scanning along the X axis and the Y axis hardly becomes unstable.

[0053]

(Fourth Embodiment)

A fourth embodiment according to the present invention will now be described with reference to FIG. 5. The scanning mechanism of this embodiment comprises, as shown in FIG. 5, a scanning mechanism holding base 501, a cylindrical actuator 502 fixed to the scanning mechanism holding base 501, and another cylindrical actuator 503 fixed to a free end of the actuator 502.

[0054]

The cylindrical actuator 502 comprises, for example, a cylindrical piezoelectric device, and such a cylindrical piezoelectric device is often used in a commercially available scanning probe microscope. The cylindrical piezoelectric

device 502 has four split electrodes 504 provided on its outer peripheral surface and an opposed electrode provided on an inner peripheral surface. The free end of the cylindrical piezoelectric device 502 can be scanned along the X axis and the Y axis by appropriately applying a voltage between these electrodes.

[0055]

The cylindrical actuator 503 comprises also, for example, a cylindrical piezoelectric device, and this is smaller than the cylindrical piezoelectric device 502 and has a higher resonance frequency than that of the cylindrical piezoelectric device 502. The cylindrical piezoelectric device 503 has one electrode provided on its outer peripheral surface and one electrode provided on an inner peripheral surface. The free end of the cylindrical piezoelectric device 503 can be scanned along the Z axis by appropriately applying a voltage between both electrodes.

[0056]

The cylindrical piezoelectric device 503 is held at a position in the vicinity of the center in dimension thereof by a member provided at the free end of the cylindrical piezoelectric device 502. Therefore, both side portions of the cylindrical piezoelectric device 503 symmetrically extend and contract in opposed directions, in accordance with application of a voltage between the electrodes, as indicated by the arrows, with its part close to the center fixed to the cylindrical piezoelectric device 502 as a reference. It is, therefore, possible to suppress the impact generated due to the extending

and contracting operation of the cylindrical piezoelectric device 503 responsible for high speed scanning along the Z axis. The scanning mechanism of this embodiment can, thus, stably operate with respect to high speed scanning with less vibrations.

[0057]

(Fifth Embodiment)

A fifth embodiment according to the present invention will now be described with reference to FIG. 6. As shown in FIG. 6, the scanning mechanism of this embodiment comprises an XY stage having a parallel spring stage structure for XY scanning and an actuator 606 which is attached to the XY stage for Z scanning. The XY stage having the parallel spring stage structure is disclosed in Jpn. Pat. Appln. KOKAI Publication No. 11-126110, and its content is incorporated in the present specification for reference.

[0058]

The XY stage has a fixed table 601 and a movable table 607, and further includes a pair of elastic members 608 and 609 provided on both sides of the movable table 607 along the Y axis, a pair of elastic members 610 and 611 provided on both sides of the movable table 607 along the X axis, a pair of X direction actuators 602 and 603 for generating displacement for moving the movable table 607 along the X axis, and a pair of Y direction actuators 604 and 605 for generating displacement for moving the movable table 607 along the Y axis.

[0059]

Each of the elastic members 608 and 609 comprises, for

example, a rectangular spring which has a slit extending along the X axis and is elongated along the X axis. Further, each elastic member has relatively high rigidity along the X axis and, on the other hand, relatively low rigidity along the Y axis. Each of the elastic members 610 and 611 comprises, for example, a rectangular spring which has a slit extending along the Y axis and is elongated along the Y axis. Each of these elastic members has relatively high rigidity along the Y axis and, on the other hand, relatively low rigidity along the X axis.

[0060]

The actuator 606 in charge of Z scanning to which high speed scanning is required comprises, for example, a stacked piezoelectric device, and this stacked piezoelectric device has a part in the vicinity of the center thereof being fixed to the movable table 607 by, e.g., an adhesive. Both side portions of the Z scanning stacked piezoelectric device 606 symmetrically extend and contract in the opposed directions in response to application of a voltage, as indicated by the arrows, with its part close to the center thereof fixed to the movable table 607 as a reference. The impact generated by the extending and contracting operation of the stacked piezoelectric device 606 can be, therefore, suppressed. Accordingly, the scanning mechanism of this embodiment can stably operate with respect to high speed scanning with less vibrations.

[0061]

A description will now be given as to comparative examples facilitating understanding of advantages of the

scanning mechanism according to the present invention hereinafter. Each of the comparative examples described below follows conventional scanning mechanisms.

[0062]

(First Comparative Example)

A first comparative example will be explained with reference to FIG. 7. As shown in FIG. 7, the scanning mechanism of this comparative example comprises a scanning mechanism holding base 701, an L-shaped actuator pedestal 702 fixed to the scanning mechanism holding base 701, two actuators 703 and 704 attached to the actuator pedestal 702, and an actuator 705 held by the two actuators 703 and 704.

[0063]

Each of the actuators 703, 704 and 705 is, for example, a stacked piezoelectric device and extendable along the X axis, the Y axis and the Z axis. Each of the X scanning stacked piezoelectric device 703 and the Y scanning stacked piezoelectric device 704 has one end portion fixed to the actuator pedestal 702. One end of the Z scanning stacked piezoelectric device 705 is fixed to the other end of each of the X scanning stacked piezoelectric device 703 and the Y scanning stacked piezoelectric device 704 by an adhesive in order to obtain a long stroke, namely, a scanning range.

[0064]

In this scanning mechanism, the extending and contracting operation of the Z scanning stacked piezoelectric device 705 generates the moment in the X scanning and Y scanning stacked piezoelectric devices 703 and 704. This produces the

vibrations, and the generated vibrations are transmitted to the actuator pedestal 702 or the scanning mechanism holding base 701 to oscillate the scanning mechanism.

[0065]

The scanning mechanism of each of the foregoing embodiments has reduced vibration noise as compared with the scanning mechanism of this comparative example.

[0066]

(Second Comparative Example)

A second comparative example will now be described with reference to FIG. 8. As shown in FIG. 8, the scanning mechanism of this comparative example comprises a scanning mechanism holding base 801, an L-shaped actuator pedestal 802 fixed to the scanning mechanism holding base 801, an X scanning actuator 803 fixed to the actuator pedestal 802, a Y scanning actuator 804 fixed to a free end portion of the X scanning actuator 803, and a Z scanning actuator 805 fixed to a free end portion of the Y scanning actuator 804.

[0067]

Each of the actuators 803, 804 and 805 comprises, for example, a stacked piezoelectric device, and these actuators are connected to each other in series with their directions changed at 90 degrees in order to obtain a long stroke, i.e., a scanning range.

[0068]

In this scanning mechanism, the extending and contracting operation of the Z scanning stacked piezoelectric device 805 generates the moment to the Y scanning stacked piezoelectric

device 804 or the X scanning stacked piezoelectric device 803, as similar to the first comparative example. This produces the vibrations, and the generated vibrations are transmitted to the actuator pedestal 802 or the scanning mechanism holding base 801, thereby oscillating the scanning mechanism.

[0069]

The scanning mechanism of each of the foregoing embodiments has reduced vibration noise as compared with the scanning mechanism of this comparative example.

[0070]

(Third Comparative Example)

A third comparative example will now be described with reference to FIG. 9. As shown in FIG. 9, the scanning mechanism of this comparative example comprises a scanning mechanism holding base 901, an L-shaped actuator pedestal 902 fixed to the scanning mechanism holding base 901, an X scanning actuator 903, a Y scanning actuator 904, and a Z scanning actuator 905. Each of the actuators 903, 904 and 905 is, for example, a stacked piezoelectric device and extendable along the X axis, the Y axis and the Z axis.

[0071]

One end portion of each of the X scanning actuator 903 and the Y scanning actuator 904 is fixed to the actuator pedestal 902, and one end portion of the Z scanning actuator 905 is fixed to the scanning mechanism holding base 901. The other end portions of the three stacked piezoelectric devices 903, 904 and 905 are connected to each other. That is, the scanning mechanism of this comparative example is of

a so-called tripod type which is the most common structure as the scanning mechanism of the scanning tunnel microscope.

[0072]

In this scanning mechanism, the counteraction of the extending and contracting operation of the Z scanning piezoelectric device 905 is directly transmitted to the scanning mechanism holding base 901 to oscillate the scanning mechanism or twist the X scanning and Y scanning stacked piezoelectric devices 903 and 904 out of shape. Further, the vibration of that operation is transmitted to the actuator pedestal 902 to oscillate the scanning mechanism.

[0073]

The scanning mechanism of each of the foregoing embodiments has reduced vibration noise as compared with the scanning mechanism of this comparative example.

[0074]

While some embodiments have been described concretely with reference to the drawings, the present invention is not limited to the aforementioned embodiments, and includes all implementations within the scope of the present invention.

[0075]

Therefore, the present specification includes the inventions described in the following articles 1 to 10.

[0076]

1. A scanning mechanism including an actuator for moving an object to be moved for a scanning operation, and a holding portion for holding the actuator, the actuator being held at a position in the vicinity of the center in dimension thereof.

[0077]

2. A scanning mechanism including an actuator for moving an object to be moved for a scanning operation, and a holding portion for holding the actuator, the actuator being held at a position in the vicinity of the center of gravity thereof.

[0078]

3. The scanning mechanism according to the above articles 1 or 2, further including a driver for moving an object to be moved for a scanning operation, the driver moving the object to be moved in a direction different from the moving direction by the actuator, and a scanning operation with respect to the moving direction by the actuator having a higher scanning frequency than scanning operations with respect to other directions.

[0079]

4. The scanning mechanism according to any one of the above articles 1 to 3, in which the actuator is a piezoelectric device.

[0080]

5. The scanning mechanism according to the above article 4, in which the piezoelectric device is a stacked piezoelectric device.

[0081]

6. The scanning mechanism according to the above article 4, in which the piezoelectric device is a cylindrical piezoelectric device.

[0082]

7. The scanning mechanism according to the above article

3, in which the driver includes another two actuators.

[0083]

8. The scanning mechanism according to the above article 3, in which the driver includes an XY stage having a parallel spring stage structure.

[0084]

9. A mechanical scanning microscope including a scanning mechanism described in any one of the above articles.

[0085]

10. A scanning probe microscope including a scanning mechanism described in any one of the above articles.

[0086]

Further, in the above-described embodiments, although the actuators which are the piezoelectric devices have been exemplified, the technical concept of suppressing the generation of vibration by holding the kinetic system of the drive portion at a position in the vicinity of the center of gravity thereof can be also applied to other actuators. For example, this can be applied to an actuator which is of a voice coil type, and similar advantages can be obtained by holding the kinetic system at a position in the vicinity of the center of gravity thereof.

[0087]

Furthermore, the scanning mechanism according to the present invention has an advantage of enabling high speed operation while suppressing the vibration as well as an advantage of reducing the scanning noise, thereby decreasing undesirable drive sounds.

[0088]

[Advantages of the Invention]

According to the present invention, there can be provided a scanning mechanism which is stable in operation and has less vibration noise by suppressing the occurrence of vibrations caused by a scanning operation. According to the present invention, in the mechanical scanning mechanism having a plurality of scanning direction, there can be provided a scanning mechanism which is stable in operation and having less vibration noise by suppressing the vibration transmitted from the drive portion in charge of a scanning operation with respect to the direction involving a highest scanning frequency.

[0089]

According to the present invention, there can be provided a mechanical scanning microscope which can stably operate a high speed scanning with less vibration noise.

[Brief Description of the Drawings]

[FIG. 1]

A view showing a scanning probe microscope having a scanning mechanism according to a first embodiment of the present invention.

[FIG. 2]

Views for explaining the scanning mechanism shown in FIG. 1; (a) is a perspective view of the scanning mechanism, which shows the scanning mechanism upside down for easy understanding; (b) is a side view of the scanning mechanism shown from a Z direction; (c) is a side view of the scanning mechanism shown from a Y direction; and FIG. 2 (d) is a side

view of the scanning mechanism shown from an X direction.

[FIG. 3]

(a) is a view for explaining the operation of the scanning mechanism illustrated in FIGS. 2 (a) to 2 (d), and (b) is a view for explaining the operation of a scanning mechanism of a second embodiment according to the present invention.

[FIG. 4]

Views for explaining the operation of a scanning mechanism of a third embodiment according to the present invention; (a) is a perspective view of the scanning mechanism, which shows the scanning mechanism upside down for easy understanding; and (b) is a side view of the scanning mechanism shown from the X direction.

[FIG. 5]

Views for explaining the operation of a scanning mechanism of a fourth embodiment according to the present invention; (a) is a perspective view of the scanning mechanism, which shows the scanning mechanism upside down for easy understanding; and (b) is a partial cross-sectional side view of the scanning mechanism.

[FIG. 6]

Views for explaining the operation of a scanning mechanism of a fifth embodiment according to the present invention; (a) is a plane view of the scanning mechanism; and (b) is a cross-sectional view of the scanning mechanism taken along the line Lx.

[FIG. 7]

Views showing a scanning mechanism of a comparative

example 1 according to a prior art for facilitating understanding the scanning mechanism according to the present invention; (a) is a perspective view of the scanning mechanism; and (b) is a partial cross-sectional side view of the scanning mechanism.

[FIG. 8]

Views showing a scanning mechanism of a comparative example 2 according to a prior art for facilitating understanding the scanning mechanism according to the present invention; (a) is a perspective view of the scanning mechanism; and (b) is a partial cross-sectional side view of the scanning mechanism.

[FIG. 9]

Views showing a scanning mechanism of a comparative example 3 according to a prior art for facilitating understanding the scanning mechanism according to the present invention; (a) is a perspective view of the scanning mechanism; and (b) is a partial cross-sectional side view of the scanning mechanism.

[Explanation of Reference Symbols]

200 … Scanning mechanism,

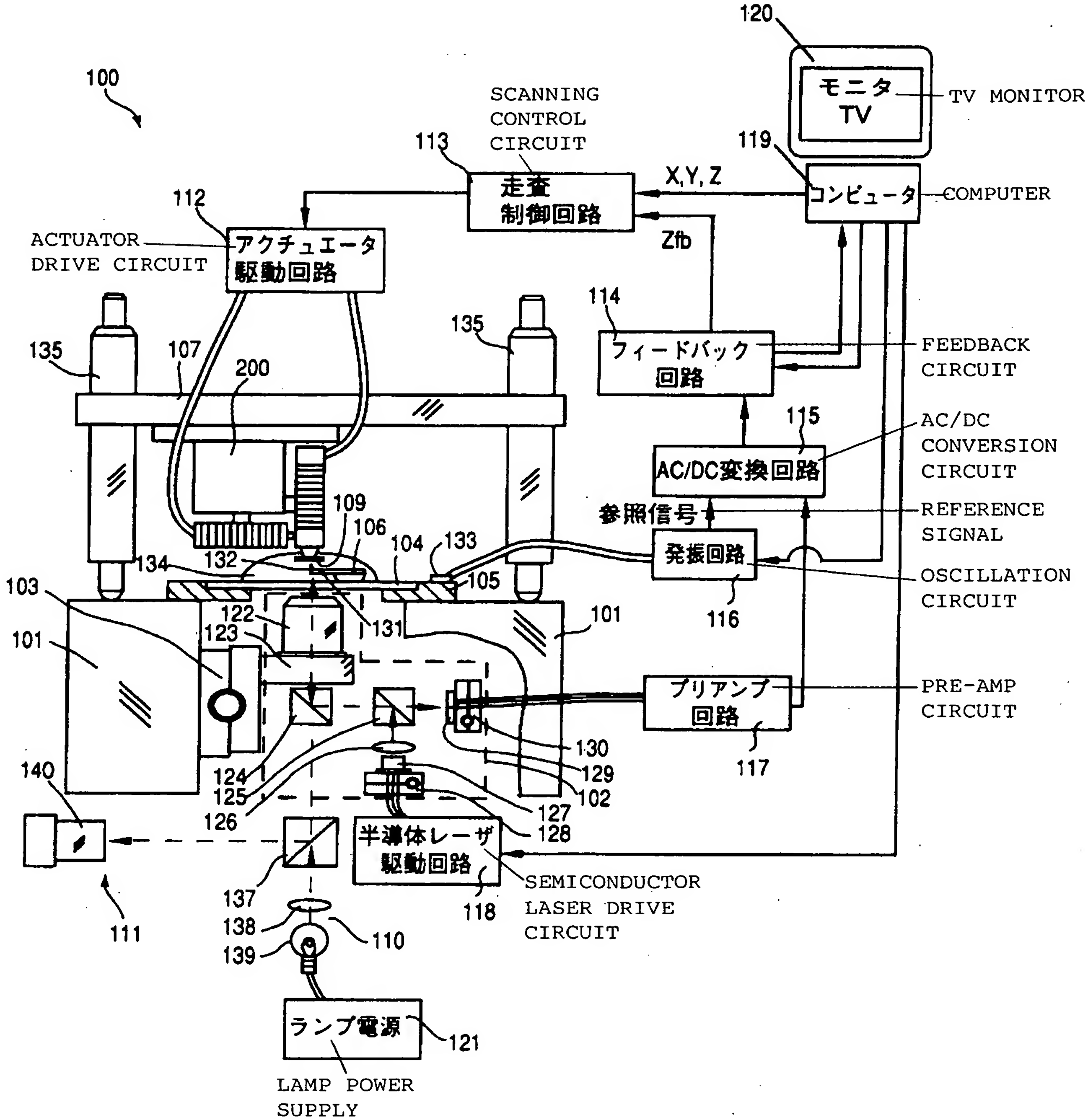
201 … Scanning mechanism holding base,

202, 203 … Actuator pedestal,

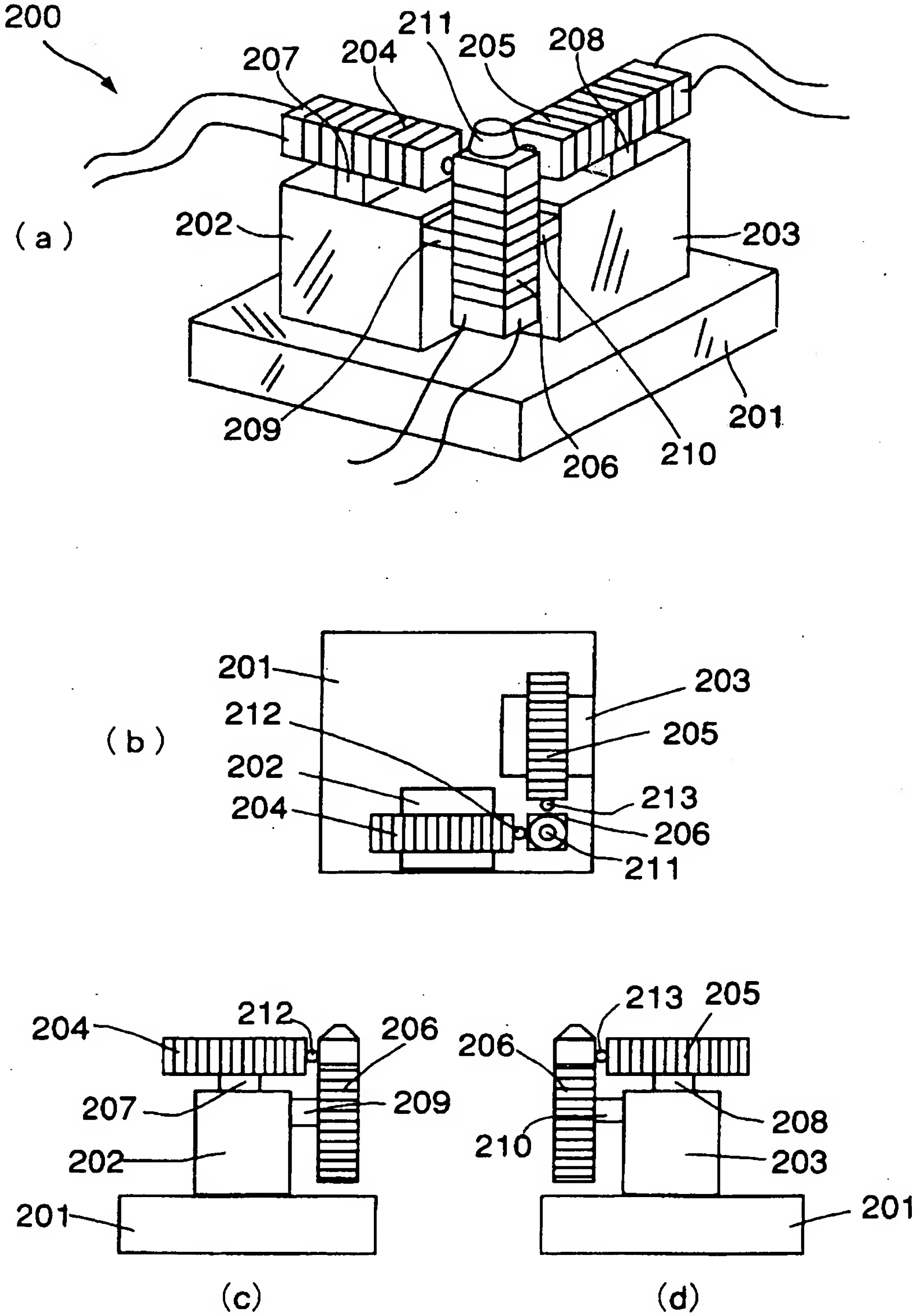
204, 205, 206 … Actuator,

207, 208, 209, 210 … Actuator holding portion.

【書類名】 図面
[NAME OF DOCUMENT] DRAWINGS
【図１】
[FIG. 1]



【図２】
[FIG. 2]


200
207
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211
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(a)
202
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201
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205
(b)
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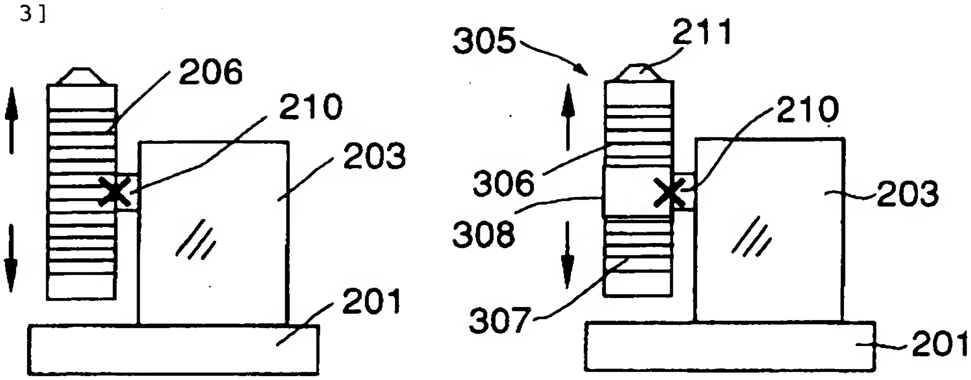
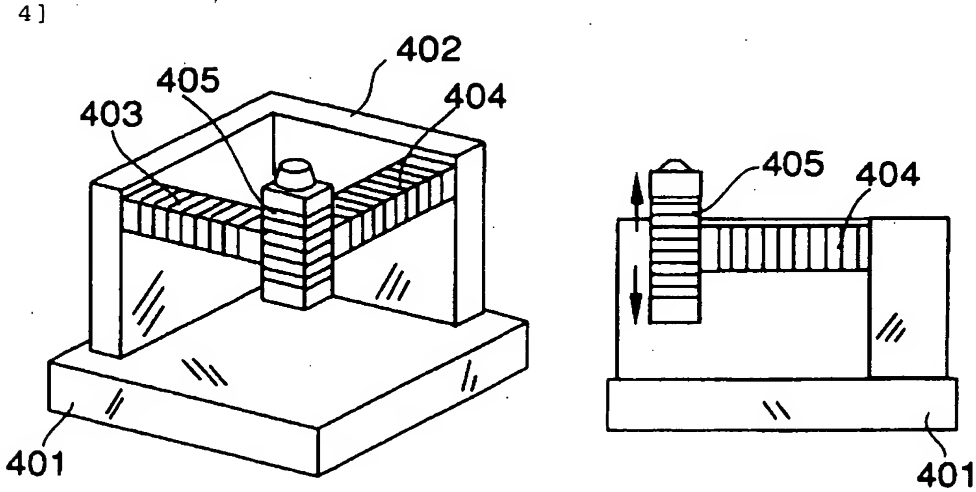
204
206
211
204
212
206
207
209
202
201
213
205
206
208
210
203
201
(c)
(d)

【図３】
[FIG. 3]



（ａ）　（ｂ）

【図４】
[FIG. 4]



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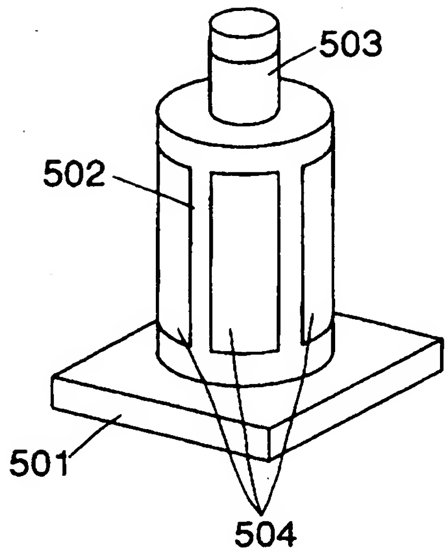
【図５】
[FIG. 5]



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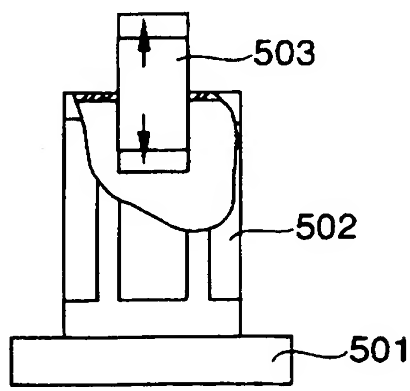

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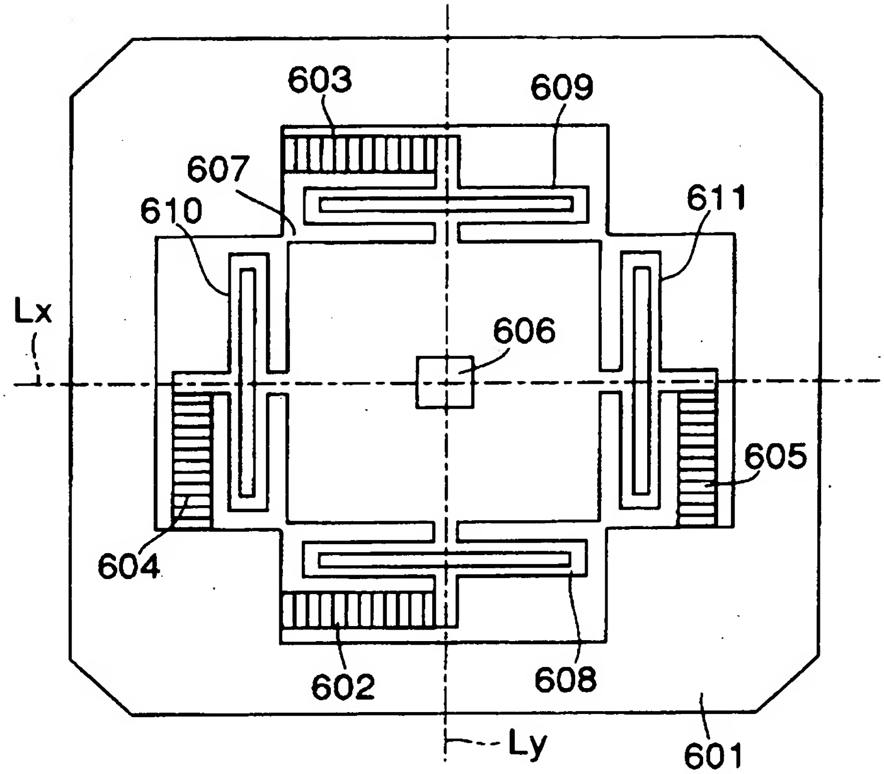
【図6】

[FIG. 6]


603
609
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610
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Lx
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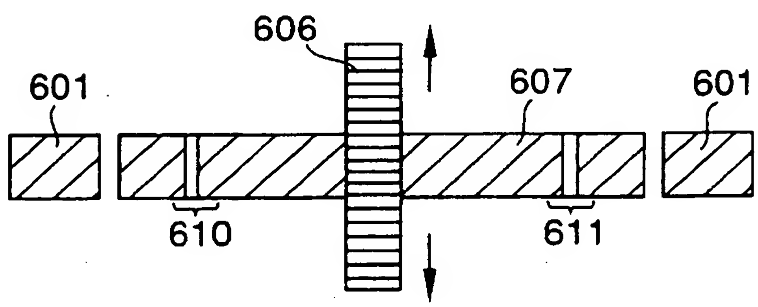
605
604
602
608
Ly
601

(a)


606
601
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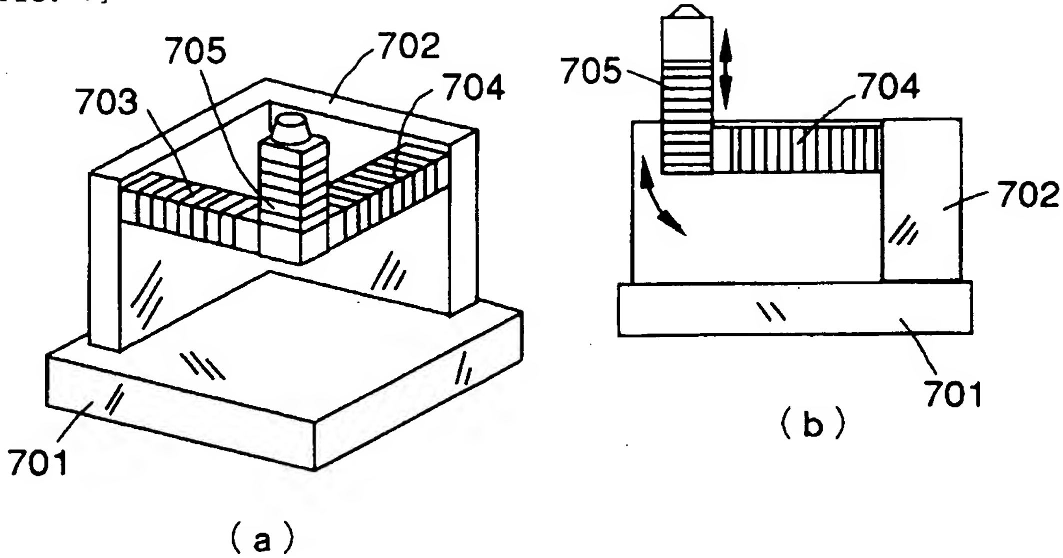
601
610
611

(b)

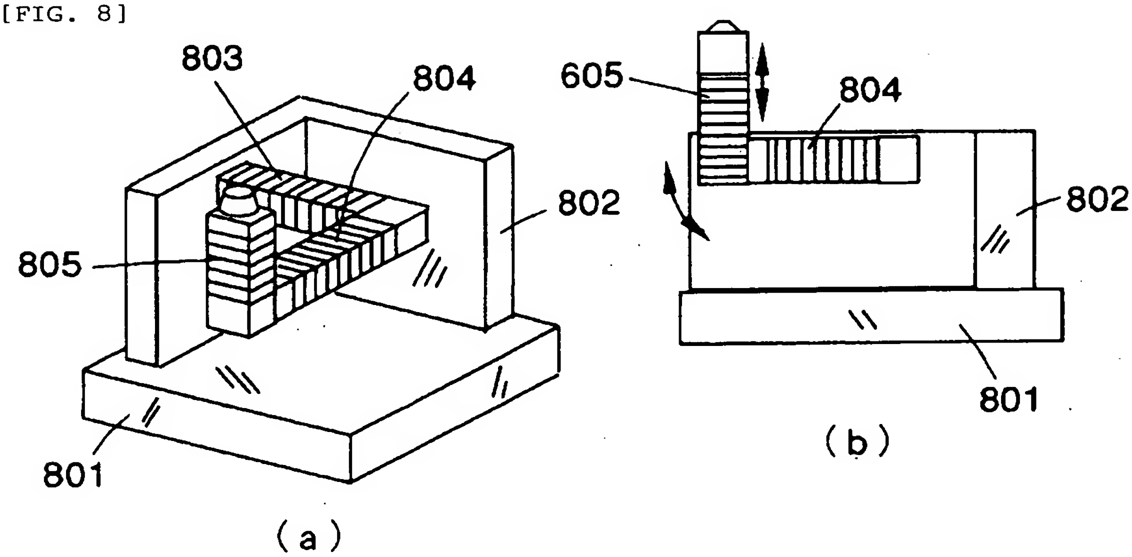
【図７】

[FIG. 7]



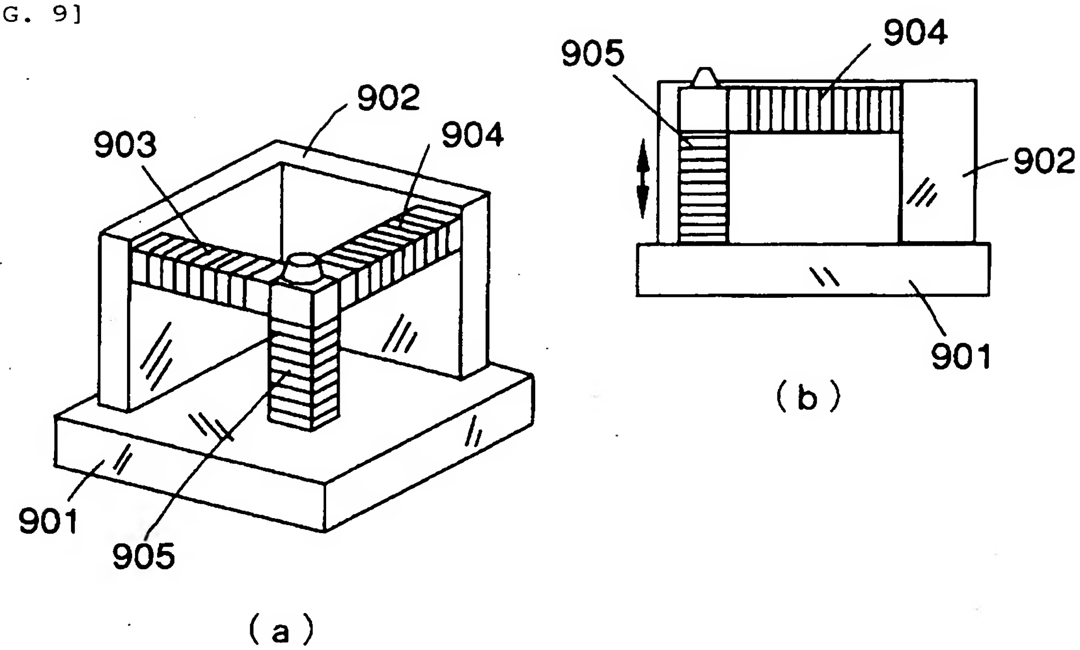
【図８】

[FIG. 8]



【図9】

[FIG. 9]



[Document] ABSTRACT

[Abstract]

[Object] An object of the present invention is to provide a scanning mechanism capable of suppressing the occurrence of vibrations and thereby stably performing a high speed scanning.

[Means for Achieving the Object] A scanning mechanism 200 comprises: a scanning mechanism holding base 201; actuator pedestals 202 and 203 fixed to the scanning mechanism holding base 201; and actuators 204, 205 and 206 attached to the actuator pedestals 202 and 203. The actuator 204 is substantially held by the actuator pedestal 202 through an actuator holding portion 207. Similarly, the actuator 205 is substantially held by the actuator pedestal 203 through an actuator holding portion 208. The actuator 206 is substantially held by the actuator pedestals 202 and 203 through actuator holding portions 209 and 210. The actuator holding portions 207 and 208 hold the actuator 204 and 205 respectively at a position in the vicinity of the center in dimension thereof. The actuator holding portions 209 and 210 hold the actuator 206 at a position in the vicinity of the center in dimension thereof.

[Elected Figure] FIG. 2

APPLICANT'S PAST DATA

Identification Number [000000376]

1. Date of Change August 20, 1990

[Reason for Change] New Registration

[Address] 43-2, Hatagaya 2-chome, Shibuya-ku, Tokyo

[Name] OLYMPUS OPTICAL CO., LTD.

APPLICANT'S PAST DATA

Identification Number	[500117794]
1. Date of Change	March 14, 2000
[Reason for Change]	New Registration
Address:	Kakuma-machi, Kanazawa-shi, Ishikawa-ken (no street number) c/o Kanazawa University
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